

### **Pros and cons of three viable options within budget guidance (not priority order)**

The Committee identified three viable options for a Phase 1 long-baseline experiment that have the potential to accomplish important science. Both long baseline and underground capabilities are critical to reach the ultimate goal of the LBNE. However we could not keep both capabilities at the first phase within the budget guideline. In order to confirm the viability of the Phase 1 options that would place the detector on the surface, we still need to resolve concerns about the ability to handle cosmic ray backgrounds. We list the pros and cons of each of the viable options below.

- 30 kton Ash River surface detector (NuMI low energy beam)
  - a. Pros:
    - i. Best Phase 1 CP sensitivity for the current value of  $\theta_{13}$  in combination with NOvA and T2K results. The sensitivity would be enhanced if the mass ordering were known.
    - ii. Excellent ( $3\sigma$ ) mass ordering reach in the negative  $\delta_{CP}$  region
  - b. Cons:
    - i. Cosmic ray backgrounds in the surface detector (impact and mitigation to be determined)
    - ii. The sensitivity will decrease if  $\theta_{13}$  turns out to be smaller than the current experimental value.
    - iii. Only accelerator-based physics
    - iv. Limited LBNE Phase 2 path
      - 1. Beam limited to 1.1 MW (Project X Stage 1) – requires some investment for the 1.1 MW beam.
      - 2. It could be a 20 kton Soudan 2300 ft detector (non-accelerator physics)
      - 3. Shorter baseline limitation
- 15 kton Soudan underground (2300 ft) detector (NuMI low energy beam)
  - a. Pros:
    - i. Broadest Phase 1 physics program
      - 1. Accelerator-based physics including good ( $2\sigma$ ) mass ordering reach in the negative  $\delta_{CP}$  region
      - 2. non-accelerator physics including proton decay, atmospheric neutrinos, and supernovae neutrinos
    - ii. Mitigate cosmic background risks
  - b. Cons:
    - i. The accelerator-based program is weaker than Ash River and Homestake options
    - ii. Limited LBNE Phase 2 path
      - 1. Beam limited to 1.1 MW (Project X Stage 1) – requires some investment for the 1.1 MW beam.
      - 2. It could be a 30 kton Ash River surface detector or an additional 20 kton Soudan 2300 ft detector
      - 3. Shorter baseline limitation

- 10 kton Homestake surface detector (new beamline)
  - a. Pros:
    - i. Excellent mass ordering reach in the full  $\delta_{CP}$  range
    - ii. Good CP violation reach
    - iii. Longer baseline
      - 1. self sufficient standard neutrino measurements
      - 2. best sensitivity to standard model tests and non-standard neutrino physics
    - iv. Clear LBNE Phase 2 path – a 25 kton detector at 4850 ft → cover the full capacity of LBNE physics program
    - v. Take full advantage of Project X
  - b. Cons:
    - i. Cosmic ray backgrounds in the surface detector (impact and mitigation to be determined)
    - ii. Only accelerator-based physics. Non-accelerator physics is delayed to Phase 2